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NSRP 0439

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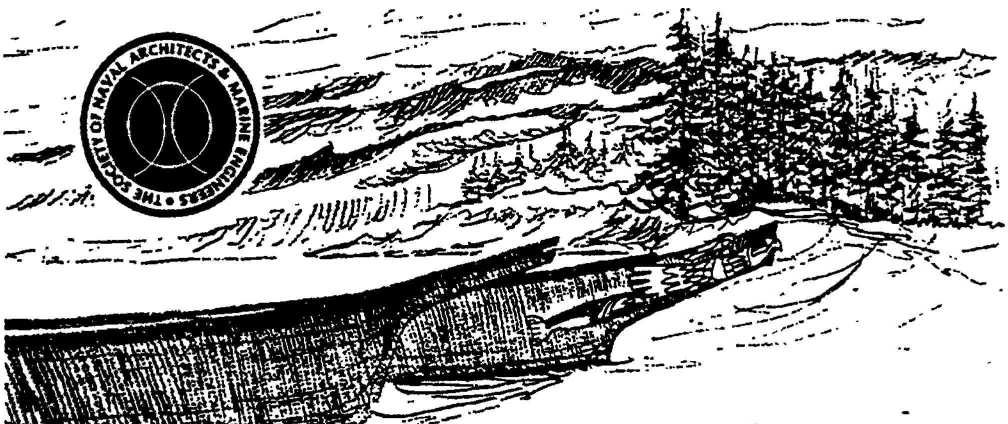

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601 Pavonia Avenue
Jersey City, New Jersey 07306
Phone (201) 798-4800
Fax (201) 798-4975

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Technology Survey of U.S. Shipyards - 1994

Richard Lee Storch (M), University of Washington, U.S.A., John Clark (V), A & P Appledore International, Ltd., U.K., and Thomas Lamb (FL), Textron Marine & Land Systems, U.S.A.

ABSTRACT

This paper reports on the results of a study of the international competitiveness of the U.S. shipbuilding industry. It describes the results of a detailed technology survey of 5 U.S. and 5 overseas shipyards. It then discusses the relative levels of technology application by the U.S. and overseas industries. A detailed competitive analysis is then presented. Finally, specific areas for improvement needed by the U.S. industry are recommended.

INTRODUCTION

Over the past decade, large U.S. shipyards involved in new construction have concentrated on the building of vessels for the U.S. government, primarily combatants and auxiliaries for the U.S. Navy. The few merchant ships that have been built were for the Jones Act trade, in which foreign shipbuilders were precluded from competing. This workload was sufficient to maintain the industry during the build up to the "600 ship Navy" in the late 1980's. Events after that have led to a dramatic downturn in shipbuilding for the U.S. Navy. As a result, U.S. shipyards must seek other customers in order to remain in business. Since the U.S. merchant ship fleet is relatively small, U.S. shipbuilders will be forced to compete for shipbuilding contracts for foreign ship operators. This puts the U.S. shipyards in direct competition with shipbuilders throughout the world.

As U.S. shipyards prepare to compete for merchant shipbuilding for export, it will be important for them to understand their worldwide competitive position. The broad objective of this work is to help provide that information. This report is the result of a study sponsored by the National Shipbuilding Research Program entitled "Requirements and Assessments for Global Shipbuilding Competitiveness" (Storch, 1994). The study was the result of a combination of three individual project abstracts, two from Panel SP-4, Design/Production Integration and one from Panel SP-1, Facilities and Environmental Effects.

There were five objectives of this research. They were:

- to determine the relative technology levels in use in shipyards in the U.S. and in leading shipyards overseas;
- to determine the relative status of shipbuilding/ship repair facilities in U.S. and leading overseas shipyards;
- to determine the facilities required by U.S. shipyards to compete against leading overseas shipyards and to evaluate the relative cost effectiveness of any required facility irnprovements;
- to provide an indication of the competitive position of U.S. shipyards in relation to the leading overseas shipyards in terms of cost and time, and to determine how overseas shipyards are currently abIe to produce ships in a shorter time and for less cost than U.S. shipyards; and
- to identify the major factors to be addressed and actions taken in order to allow U.S. shipyards to enter the international shipbuilding/ ship repair market on a competitive basis, relating to technology levels, operational practices (both internal and external to a shipyard), and facilities.

A key element of the research was a detailed survey of 10 shipyards. 5 in the U. S., 4 in Western Europe and 1 in Japan. These surveys were used, along with other sources, to obtain answers to the questions posed by the 5 objectives of the research listed above. The data associated with each individual shipyard survey will he kept confidential. us agreed to by the

study team and the shipyards involved. Thus the results are averages, used to determine trends and general levels, rather than relating to specific shipyards. The research team believes the cross section of shipyards surveyed provides a valid description of the current state of international and U.S. shipbuilding competitiveness. Although 5 U.S. yards were surveyed, this paper uses data from only the 4 large yards, in order to provide a better base for comparison.

TECHNOLOGY SURVEY

The technology survey performed not only examines how up to date a shipyard's hardware and facilities are, but also the procedures used to operate them, the methods used to plan and control the work and the production of engineering information. The results of a survey are an important indicator of a shipyard's performance and capability and can be used to compare shipyards anywhere in the world.

For the proposes of a full technology survey the overall shipbuilding process is divided into 72 elements which cover the whole operation (A&P Appledore, undated). However, for this survey of U.S. shipyards the three elements relating to amenities (canteen, washrooms and other amenities) were not addressed. The remaining 69 elements are shown in Table I.

The measurement of the efficiency of each element, in terms of technology levels, provides a consistent method of comparing different shipyards. When more than one surveyor is used for the examination the results become more objective. Three surveyors were used for most of the shipyard visits for this project. In order to take account of their relative importance in the shipbuilding process, weightings are applied to each element and group of elements.

Five levels of technology have been identified. These correspond to the state of development of the most advanced shipyards at different times over the last 34 years. Those yards which are less advanced remain at the level of technology of an earlier period. The technology level is described for the whole yard, for the seven major areas of shipyard operation, and for the 69 individual elements. In each case, the yard under review is rated according to the description which most closely matches its situation. In this way a consistent assessment can be made, and the results of the review used to compare shipyards.

For the whole shipyard, the five levels of technology are described below:

Level 1 reflects shipyard practice of 1960. The shipyard has small cranes, several berths in use and very little mechanization. Outfitting is largely carried out on board ship after launch. Operating systems are basic and manual.

Level 2 is the technology employed in shipyards modernized during the late 1960's or the early 1970's. Fewer berths are in use, or possibly a building dock, larger cranes and some degree of mechanization. Computing is used. for some of operating systems.

Level 3 is good shipbuilding practice of the late 1970's. It is represented by the new or fully redeveloped shipyards in the U.S., Europe or Japan. There are large cranes, some environmental protection and a single dock or level construction area. A large degree of mechanization and the use of computers is evident.

Level 4 refers to shipyards that have continued to advance their technology during the 1980's. Generally a single dock is used, with good environmental protection. Fully developed operating systems and extensive early outfitting are evident.

Level 5 represents state of the art shipbuilding technology in 1990. It is developed from level 4 by means of automation in areas where it can be used effectively, and by integration of the operating systems, for example by the effective use of CAD. It is characterized by efficient, computer aided material control and by effective quality assurance.

COMPENSATED GROSS TONNAGE

Compensated Gross Tonnage (CGT) is used to provide a common yardstick to reflect the relative output of merchant shipbuilding activity in large aggregates such as "World", "Regions" or "Groups of many yards" (Bruce, 1992). The compensation of the measured Gross Tonnage is to take into account the influence of ship type, complexity and size on work content. For example, the work content of a passenger ship per Gross Ton is larger than that of a tanker or bulk carroer.

In 1984, the present system of calculating CGT was adopted by the Organization for Economic Cooperation. and Development (OECD), the

Association of West European Shipbuilders (AWES) and the Shipbuilders' Association of Japan (SAJ). The coefficients are currently under review, particularly to accommodate double hulled tankers.

Because the system was intended to measure the relative output of large groups of shipyards, it has had to be modified slightly for application to small groups or individual shipyards. The coefficients for converting GT to CGT cover bands of sizes within the different ship types. Thus, each ship type is covered by a step function which can cause anomalies when ships have only slightly different deadweights and could have coefficients with significantly different values applied. To overcome this, and make the measure useful for performance comparisons of individual shipyards, the coefficients have been plotted for each ship type and values located at the mid point of the range of sizes to which they relate. Curves were then drawn through the points and these curves we used to determine the coefficient to apply.

The relative position of a shipyard gives guidance as to the improvement in cost or performance needed to become competitive. There is generally a reasonable correlation between the global performance of a shipyard and the performance of each part of the shipyard. Mismatches between global and local performance could indicate bottlenecks to productivity improvement. The necessary global performance assists target setting for local performance parameters.

The comparative measure used for assessing the individual shipyard's performance is its labor cost of producing a CGT. To compare with shipyards worldwide, the cost is converted to U.S. Dollars. The Cost/CGT is not based upon the total cost of building a ship, as materials are not included. The measure is, however, directly related to the efficiency and competitiveness of a shipyard, as the labor costs are those most under its control.

In order to derive the Cost/CGT the productivity of the shipyard's employees in terms of Employee Years to produce a CGT and the Cost of an Employee Year must be derived, i.e.:

$$\text{Cost/CGT} = \text{Cost/Employee Year} \times \text{Employee Years/CGT} \qquad (1)$$

Another useful measure of a shipyard's productivity is the number of direct worker man-hours required to produce a CGT.

REQUIRED INFORMATION

In order to evaluate competitiveness, a substantial amount of information has to be obtained for a shipyard. This information is described below.

Ship Production

To assess recent productivity, details of the ships completed over the previous three years should be obtained. Three year's data is required as a minimum in order to average out the effects of ships in the process of being built at the beginning and the end of the period. The required information is ship type, deadweight and gross tonnages, and the applicable CGT coefficient. The initial information is obtained from the shipyard while the CGT Coefficient can be obtained from the CGT Coefficient plots mentioned earlier. CGT is obtained by multiplying the GT by the CGT Coefficient. In order to obtain the average annual output of the shipyard, the CGTs are summed and divided by the number of years of output represented.

Shipyard Personnel

Productivity is measured by the effort, in terms of man-hours required to produce an amount of work (in this case CGT). Annual numbers are required for the following people who are employed in shipbuilding activities (i.e., excluding ship repair or any other industrial activity):

- direct shipbuilding workers;
- direct shipbuilding subcontractors;
- indirect shipbuilding workers; and
- indirect shipbuilding subcontractors.

The definition of direct and indirect workers, and subcontractors varies with country and with shipyards within countries so some adjustments to the supplied figures may be necessary. Occasionally the personnel may be subdivided into direct, indirect and administrative indirect. Whatever the subdivisions used the total number of employees involved in shipbuilding is given by the sum of the direct workers and the indirect workers (including the relevant subcontractors).

Ideally the above information should be obtained for each workshop and department within a shipyard as it may be useful in assessing the productivities of the various activities in the shipbuilding process for later, more detailed studies. It is however imperative

to obtain total numbers. Where shift working is in force the numbers of workers on each shift should be obtained, again subdivided as shown above.

Work Pattern

The number of hours which are worked by shipyard personnel varies from country to country and should be ascertained for each shipyard. The number of hours which are used in calculating the cost of personnel must relate to information obtained upon the total salary costs and will include items such as overtime and shifts worked. These items must be included as they usually attract a premium above the base rate salary. As a large proportion of overheads are fixed, taking account of overtime and shift working can actually reduce the hourly charge rate required. Information required includes

- number of working days per week;
- number of working hours per week;
- number of days statutory, or public, holiday in a year;
- number of days vacation in a year;
- average number of hours overtime worked by an individual per year;
- average percentage of absenteeism in a year; and
- number of shifts worked per day.

Man-Hours Used In production

In theory if the number of direct workers and the hours worked per year are known then the total man-hours used in producing the work in a year is the product of these figures. In practice if the actual man-hours charged against contracts is obtained and summed, there is usually a discrepancy. If there is a discrepancy the reason for it should be ascertained.

To perform the check above, the actual recorded man-hours of all of the direct workers (shipyard and subcontractors) should be obtained for each ship during the time period for which the information on ships delivered was received. If the man-hours can be obtained for each trade within each workshop, or department, then this would provide useful information for any subsequent, more detailed, investigations. The annual average direct man-hours will be obtained by summing all of the man-hours per ship and dividing by the relevant number of years.

Financial Information

To obtain the cost of producing a CGT, full financial particulars of a shipyard are required. These particulars must include the following for the latest available financial year:

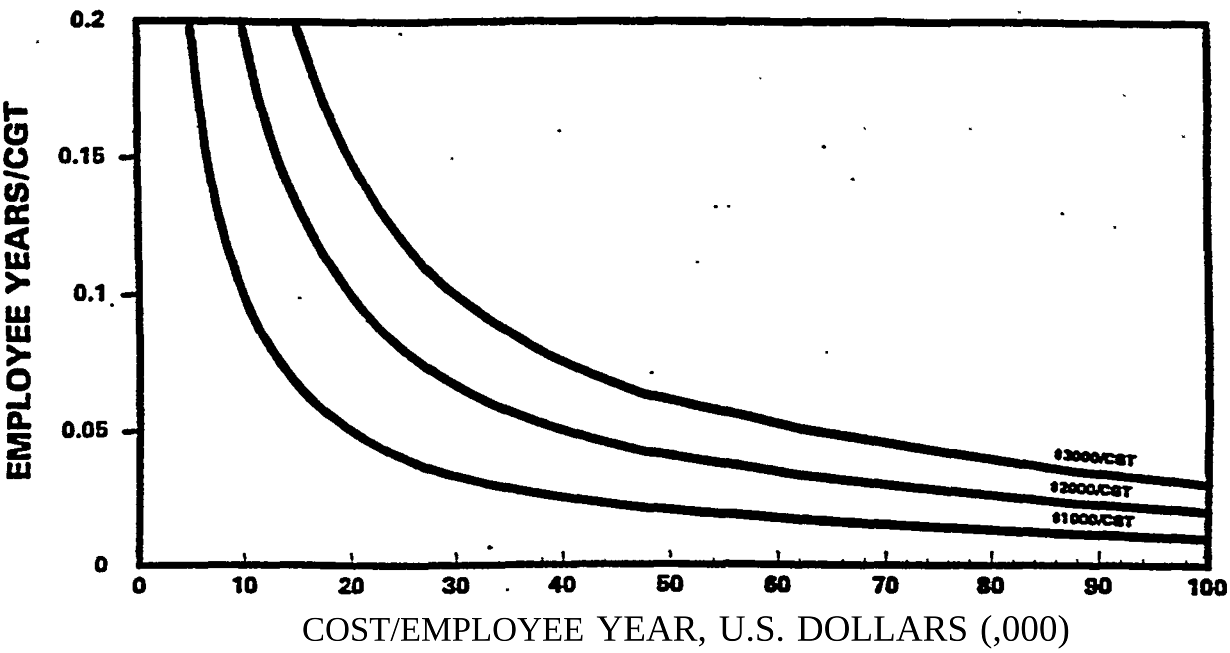
- total salaries paid to the shipyard direct workers for work related to shipbuilding, including basic salary, overtime, and bonuses;
- total costs of direct subcontractors employed for shipbuilding;
- total salaries paid to shipyard indirect workers for work related to shipbuilding (these salaries should include the same payments as for the direct workers);
- total costs of indirect subcontractors employed on shipbuilding related tasks;
- total social costs of employing the above direct workers;
- total social costs of employing the above indirect workers;
- total cost of materials and services necessary for running the business but not chargeable to specific contracts; and
- overhead costs (these should be divided into fixed and variable overheads).

UPDATING OF DATABASE

A database of the results of shipyard productivity and competitiveness surveys was used in this study (A&P Appledore, undated). All data in this database represents a snapshot in time and will be out of date unless it is updated All information is dated and has the relevant exchange rate against the U.S. Dollar recorded with it. The information obtained from the shipyards surveyed for this project is among the most up to date available and was entered into the database. It was also used to help update the remaining data in the database.

METHODOLOGY

The average annual output in terms of CGT is obtained from the ship production information. Man-hours expended in producing the above output can be calculated by using the average number of employees over the same time period as the output information in association with their working pattern. Alternatively, it may be obtained by using the actual man-hours recorded against each ship during the same time



COST PER CGT = COST/EMPLOYEE YEAR x EMPLOYEE YEAR/CGT

Figure 1 constant cost Curves

period. The average annual man-hours expended is the total man-hours expended divided by the relevant number of years. The annual cost of employing a shipbuilding employee is derived by-first determining the annual operational cost of the shipyard as the summation of:

- total annual salary cost of direct and indirect workers;
- total annual social cost of employing direct and indirect workers;
- total annual cost of direct and indirect subcontractors;
- total annual cost of materials and services necessary for running the business but not chargeable to contracts;
- annual variable overheads; and
- annual fixed overheads.

The latest available figures should be used. The cost per year of employing a shipbuilding employee is the ratio of the annual operational cost of the shipyard to the total number of shipbuilding employees. The number of employees must relate to the time period for which the financial information was obtained. Total number of shipbuilding employees is used to avoid confusion caused by different definitions of direct and indirect employees.

The cost of producing a CGT is calculated as follows:

$$\text{EMPLOYEE MAN-HOURS/CGT} = \frac{\text{AVG. ANNUAL MAN-HOURS EXPENDED}}{\text{AVG. ANNUAL OUTPUT IN CGT}} \quad (2)$$

$$\text{EMPLOYEE YEARS/CGT} = \frac{\text{EMPLOYEE MAN-HOURS/CGT}}{\text{AVG. HOURS WORKED/YEAR}} \quad (3)$$

$$\text{COST/CGT} = \frac{\text{COST}}{\text{EMPLOYEE YEAR}} \quad \frac{\text{EMPLOYEE YEARS}}{\text{CGT}} \qquad (4)$$

The COST/CGT calculated above is in the local currency of the country with which the shipyard is located. In order to compare with other shipyards worldwide the value is converted into U.S. Dollars by multiplying by the relevant exchange rate.

To compare shipyards throughout the world a plot of employee years per CGT versus cost per employee year is used. On this graph are curves of constant cost per CGT. The calculated values for any shipyard or shipbuilding country/region can be plotted on this graph to indicate their relative performances (see Figure 1).

The value plotted on the horizontal axis only represents a snapshot in time for the various shipyards and countries since costs and exchange rates change continuously. To alleviate this problem, the dates when each data item on the graph was calculated are recorded and the salary levels and exchange rate used are noted Salary levels in these countries are tracked so that costs can be adjusted to suit and current exchange rates are applied to obtain the latest values for the cost per employee year. Productivity will also change over time and if any reliable information is obtained about this it is also incorporated.

The overall productivity of shipyards has to be measured over long periods of time, three years for merchant shipbuilders and five years for naval shipbuilder. Two pieces of information are required in order to calculate productivity, including the output in terms of CGT and the effort in terms of man-hours required to produce it.

Information on costs is often difficult to obtain as it is commercially sensitive and requires more effort by the shipyard to produce. Some shipyards will provide the information but if they do not then recourse to other sources is made. A number of industry associations of shipbuilding countries keep track of the relevant wage rates of competitor nations. Reports of this information adjusted to account for overhead costs, can be used.

A shipyard's current competitive position is obtained by multiplying the productivity in terms of employee years required to produce a CGT by the total cost per employee year to obtain the cost of producing a CGT in U.S. Dollars.

ESTIMATE OF CGT COEFFICIENT FOR NAVAL SHIPS

CGT Coefficients onIy exist for merchant ships and, as the vast majority of the current output of the U.S. shipbuilding industry is naval ships, an estimate of equivalent CGT Coefficients for such vessels is required in order to compare productivity with competitor shipyards. An estimate of such a coefficient has been produced as a part of this study. It should be stressed that this is only an estimate produced in order to place the U.S. shipyards in their relative competitive position in world shipbuilding, and should not be taken as the definitive COT coefficient for naval ships. To develop such coefficients would require a large scaIe study and the cooperation of naval shipbuilders worldwide.

in order to produce an estimateof CGT Coefficients for naval ships, data on 30 different vessels was used. These were all first ships in a series because they include all engineering and other non-repetitive man-hours and a significant number of merchant shipbuilding orders are for single ships. The naval ships for which information was available varied between 33m (100 ft.) Fast Patrol Craft to 196m (650 ft.) Submarine Tenders and were built in Canada, France, Germany, Italy, Spain, the U.K., and the U.S. 67% were built in Europe and 33% built in North America.

Figure 2 shows a plot of the values derived and the resultant curve drawn through them. This figure can be used to pick off the estimated CGT Coefficient for any naval ship having a GT of up to 120,000. It is stressed that the curve is based upon sparse data, but it has the advantage of varying with size of ship in the same manner as the coefficients for commercial ships.

U.S. SHIPYARDS COMPARED TO FOREIGN COMPETITORS

As part of the study five foreign shipyards were visited and their technology levels assessed. For three of them their productivity was also derived. The foreign shipyards visited were:

- AESA Sestao Yard, spain;
- Harland and Wolff, U.K.;
- IHI Kure Yard, Japan;
- Kvaemer Govan, U.K.; and
- Odensc, Denmark.

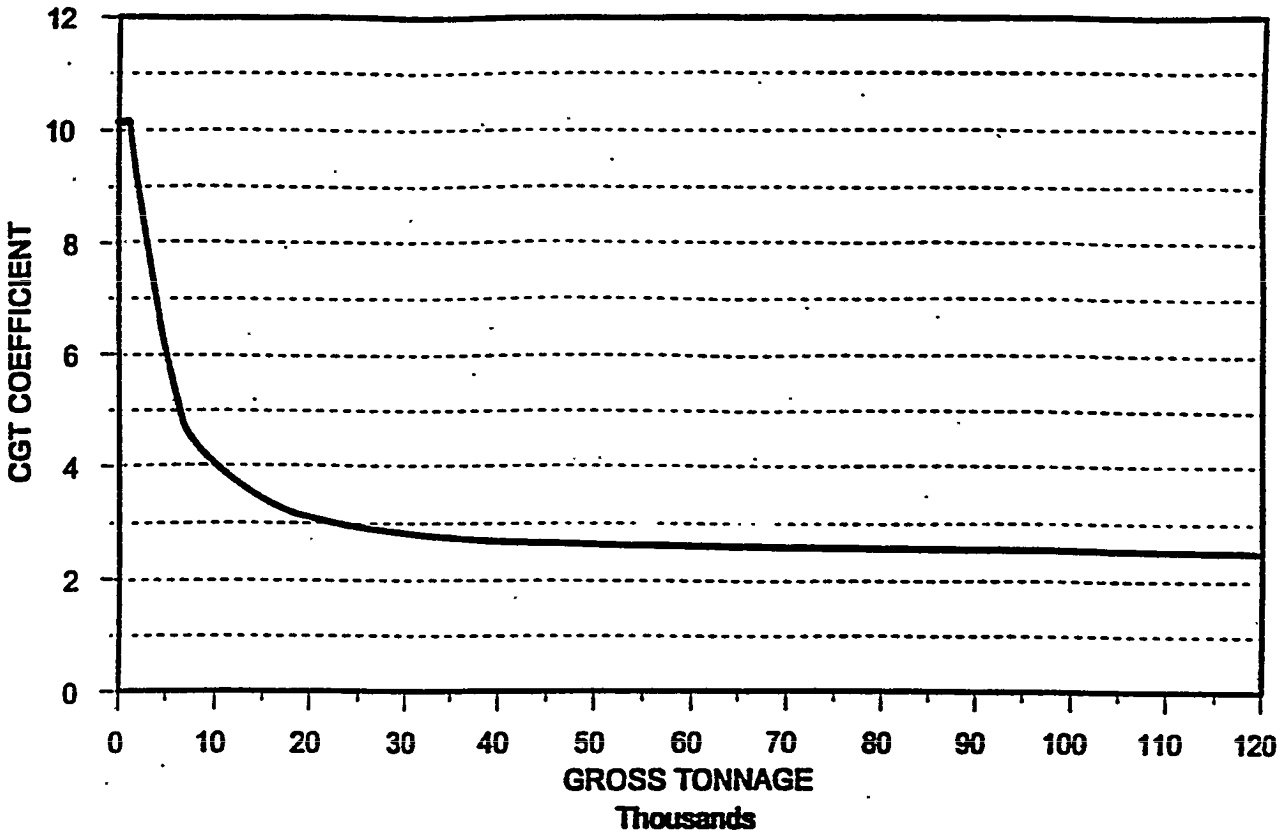


Figure 2 CGT Coefficients for Naval Vessels

These shipyards are all capable of building the ships which the four large U.S. shipyards visited can build and are thus direct competitors for building commercial ships.

LEVELS OF TECHNOLOGY

Three average levels of technology were calculated. These were for:

- the four large U.S. shipyards visited;
- the five foreign shipyards visited;
- world shipyards of about the same size as the surveyed yards and which are direct competitors (excludes U.S. shipyards but includes the five foreign shipyards visited).

The average values for each of the surveyed elements of the four large U.S. shipyards and the five foreign shipyards are shown in Table I, together with their overall technology levels. Table I shows that the four large U.S. shipyards have an average technology level of 3.4. while the five foreign yards averaged 4.0. The spread of overall technology levels for the surveyed yards is shown in Table II.

Table II shows that the U.S. shipyards are grouped very closely together in terms of technology level, and that they are as good as the lowest two of the foreign shipyards surveyed. However, the best three competitors which were visited are some five to ten years ahead in terms of shipbuilding technology. At least one of the foreign competitors having a low technology level is known to be striving to rapidly improve this with external assistance.

Technology levels of shipyards which are direct competitors to U.S. shipyards, including the five foreign shipyards surveyed, average 3.5, with a range of from 1.8 to 4.6. Thirty five shipyards were considered, from the following areas:

- Croatia;
- Far East, excluding Japan and Korea;
- Finland;
- Japan;

Label	Activity	Technology Level US Shipyards	Technology Level Foreign Shipyards	Weighting	Weighted Level US Shipyards	Weighted Level Foreign Shipyards
A1	Plate stockyard and treatment	2.9	2.9	0.500	0.145	0.145
A2	Stiffener stockyard and treatment	2.8	2.9	0.040	0.112	0.116
A3	Plate cutting	3.8	4.0	0.090	0.342	0.360
A4	Stiffener cutting	2.1	3.4	0.080	0.168	0.272
A5	Plate and stiffener forming	2.8	3.2	0.080	0.224	0.256
A6	Subassembly	2.6	3.4	0.120	0.312	0.408
A7	Flat unit assembly	2.9	3.2	0.130	0.377	0.416
A8	Curved and corrugated unit assembly	2.9	3.4	0.150	0.435	0.510
A9	3D unit assembly	3.1	3.9	0.110	0.341	0.429
A10	Superstructure unit assembly	3.0	3.4	0.100	0.300	0.340
A11	Outfit steelwork	3.0	4.1	0.050	0.150	0.205
A	STEELWORK PRODUCTION			0.156	2.906	3.457
B1	Pipework	3.3	3.3	0.190	0.627	0.627
B2	Engineering	2.8	3.0	0.130	0.364	0.390
B3	Blacksmiths	3.3	3.8	0.050	0.165	0.190
B4	Sheet metal work	2.9	4.3	0.150	0.435	0.645
B5	Woodworking	3.5	3.7	0.100	0.350	0.370
B6	Electrical	3.5	4.0	0.090	0.315	0.360
B7	Rigging	3.0	3.5	0.050	0.150	0.175
B8	Maintenance	3.8	3.6	0.060	0.228	0.216
B9	Garage	3.6	3.8	0.040	0.144	0.152
B10	General storage	3.6	4.4	0.070	0.252	0.308
B11	Auxiliary storage	3.9	4.5	0.070	0.273	0.315
B	OUTFIT PRODUCTION AND STORES			0.115	3.303	3.748
C1	Module building	3.3	3.9	0.180	0.594	0.702
C2	Outfit parts marshalling	5.0	4.0	0.200	1.000	0.800
C3	Pre-erection outfitting	3.4	4.1	0.210	0.714	0.861
C4	Block assembly	3.8	4.2	0.220	0.836	0.924
C5	Unit and block storage	3.6	4.7	0.070	0.252	0.329
C6	Materials handling	3.6	3.7	0.120	0.432	0.444
C	OTHER PRE-ERECTION ACTIVITIES			0.167	3.828	4.060

Table I Summary of Average Technology Levels for Large U.S. Shipyards and Visited Foreign Competitors

Label	Activity	Technology Level US Shipyards	Technology Level Foreign Shipyards	Weighting	Weighted Level US Shipyards	Weighted Level Foreign Shipyards
D1	Ship construction	3.0	3.7	0.090	0.270	0.333
D2	Erection and fairing	2.8	4.0	0.100	0.280	0.400
D3	Welding	3.3	3.6	0.100	0.330	0.360
D4	Onboard services	3.4	4.4	0.060	0.204	0.264
D5	Staging and access	2.6	3.5	0.080	0.208	0.280
D6	Pipework	3.5	4.1	0.100	0.350	0.410
D7	Engine room machinery	3.3	4.5	0.050	0.165	0.225
8	Hull engineenng	3.4	4.5	0.050	0.170	0.225
9	Sheet metal work	3.5	4.5	0.040	0.140	0.180
10	Woodwork	2.5	3.7	0.040	0.100	0.148
11	Electrical	3.1	4.0	0.070	0.217	0.280
12	Painting	2.6	3.5	0.080	0.208	0.280
13	Testing and commissionmg	4.3	4.7	0.090	0.387	0.423
14	After launch	3.1	3.5	0.050	0.155	0.175
)	SHIP CONSTRUCTION			0.167	3.184	3.983
E1	Layout and material now	26	3.1	0.320	0.832	0.992
E2	General environmental	3.1	3.5	0.300	0.930	1.050
E3	Lighting and heating	3.5	3.1	0.150	0.560	0.496
24	Noise. Ventilation and fume extraction	28	3.5	0.220	0.616	0,770
E	LAYOUT AND ENVIRONMENT			0.083	2938	3.308
G1	Ship design	3.1	4.0	0.120	0.372	0.480
G2	Steelwork drawing presentation	3.3	4.4	0.100	0.330	0.440
G3	Outfit drawing presentation	3.3	4.5	0.100	0.330	0.450
G4	Steelwork coding system	4.5	5.0	0.070	0.315	0.350
G5	Parts listing procedures	4.5	5.0	0.100	0.450	0.500
G6	Production engineering	3.1	4.0	0.330	0.403	0.520
G7	Design for production	3.1	4.1	0.160	0.496	0.655
G8	Dimensional and quality control	3.0	4.1	0.130	0.390	0.533
G9	Lofting methods	4.0	4.5	0.090	0.360	0.405
G	DESIGN/DRAUGHTING/PRODUCTION ENGINEERING/LOFFTING			0.166	3.446	4.334

Table I (cont.)

Label	Activity	Technology Level US Shipyards	Technology Level Foreign Shipyards	Weighting	Weighted Level US Shipyards	Weighted Level Foreign Shipyards
H1	Organisation	2 5	4.4	0.120	0.300	0.528
H2	Contract scheduling	3.8	4.8	0.060	0.228	0.288
H3	Steelwork production scheduling	4.4	4.9	0.070	0.308	0.343
H4	Outfit production scheduling	4.4	4.8	0.080	0.264	0.288
H5	Outfit installation scheduling	4.5	4.9	0.070	0.315	0.343
H6	Ship construction scheduling	4.4	4.8	0.070	0.308	0.336
H7	Steelwork production control	4.0	4.6	0.070	0.280	0.322
H8	Outfit production control	4.0	4.6	0.070	0.280	0.322
H9	Outfit installation control	4.0	4.6	0.080	0.320	0.368
H1O	Ship construction control	4.0	4.6	0.080	0.320	0.368
H11	stores control	4.3	4.8	0.070	0.301	0.336
H12	Performance and efficiency calculations	4.6	4.9	0.050	0.230	0.2451
H13	Computer applications	3.8	4.0	0.050	0.190	0.200
H14	Purchasing	4.9	4.8	0.080	0.392	0.384
H	ORGANISATION AND 0PERATING SYSTEMS			0.146	4.036	4.671
	SHIPYARD TECHNOLOGY LEVEL = $\sum_{A}^{H}$ (Sum of Products x Group Weighting)			1.000	3.409	3.989
					3.4	4.0

Table I (cont.)

- Korea;
- Poland;
- Russia;
- South America;
- Ukrain; and
- West Europe.

The U.S. shipyards are therefore operating at about the average technology level of their foreign competitors but a cause for concern is that all shipyards operating at a lower level of technology have very much lower labor rates. This also applies to Korean shipyards which have a higher level of technology than the U.S. shipyards.

DETAILED DIFFERENCES IN TECHNOLOGY LEVELS

The relative strengths and weaknesses of the U.S. shipyards have been compared with the five foreign shipyards surveyed and these are discussed below. The comments relating to the current good practices of the competitors relate to all of the shipyards worldwide which have high levels of technology. This discussion is based on the actual observations of work being performed at the five U.S. shipyards during April, 1994. All the shipbuilding was for U.S. government orders (primarily U.S. Navy) or other militay vessels. The work practices in the U.S. yards for military vessels are thus being compared to best commercial shipbuilding practices worldwide.

OVERALL TECHNOLOGY LEVEL

YARD	US. YARDS	FOREIGN YARDS
1	3.2	3.0
2	3.4	3.3
3	3.4	4.1
4	3.5	4.4
5	.	4.5

Table II Overall Technology Levels of Surveyed Yards

At the group level the U.S. shipyards have a lower level of technology for each area The differences can broadly be divided into large (over 0.75), medium (0.4 to 0.75) and small (less than 0.4).

LARGE DIFFERENCES

Ship Construction & Outfit Installation

There is no element of this group in which the U.S. shipyards are the equal of the foreign yards. The following elements all have a technology level at least 0.9 lower than the foreign shipyards.

Erection and Fairing All U.S. yards leave excess stock upon the blocks which arc to be erected. Accuracy control should be developed to the level where this can be avoided. Although in most yards the shell plating on blocks was fair, the internal decks and longitudinal bulkheads suffered from a great deal of distortion, leading to excessive times for fairing. Welded fairing aids are also used extensively.

(Onboard Services There was some evidence of pre-planned routing of services in the U.S. shipyards and the leading of the services overhead so that the decks were clear. However, the foreign shipyards have formal plans for routing of services and arranging them in a modular form so that each can be expanded or withdrawn without disruption to the remaining ones. The foreign yards also required less onboard services because a larger percentage of the work had been performed prior to erection.

Staging and Access The amount of staging used in the U.S. shipyards was far in excess of that used in the foreign shipyards and a large amount of it was of the scaffolding and wooden plank type. The requirement for a good deal of staging was avoided by the foreign yards since they paint blocks before hull erection and subsequently use “cherry pickers,” or similar, to paint in way of berth joints, or even to paint the complete exterior shell before launch. The pre-planning and performing of work at the unit/block stage which can be accessed without the need for staging also reduces the requirement for staging. The foreign shipyards visited were better than the U.S. shipyards at this.

Engine Room Machinery Although a considerable amount of pre-erection outfitting in the machinery spaces occurs at all of the U.S. shipyards surveyed, it falls well below that achieved in the foreign shipyards visited. One reason given by the U.S. shipyards is that the machinery spaces in the naval ships which they are building are extremely cramped and it is difficult to get things in. In fact, this makes it more imperative that as much machinery installation and other outfit activities as possible take place while the spaces are open and easily accessed. A number of the foreign shipyards also have formal self-checking statistical process control systems which means that their processes are under control (in the statistical meaning of the phrase).

Hull Engineering The comments on Engine Room Machinery all apply equally to Hull Engineering.

Sheet Metal Work Apart from some ventilation ducting there is very little sheet. metal work installed before launch in U.S. shipyards. This not the case in the foreign shipyards, where sheet metal for use in accommodation spaces is often installed on-unit. A good deal of the ventilation ducting installed on block is actually fitted in the overhead position with the block in its final orientation. This work needs to be performed earlier, when the deckhead is in the

inverted position. Again, a number of the foreign shipyards have formal self-check statistical process control systems in place.

Woodwork Although a number of the U.S. shipyards subcontract the making of furniture and produce joiner panels pre-cut to size in the workshop, this is all installed after launch. As a minimum, all foreign shipyards visited erected the superstructures and deckhouses almost completely outfitted. Modular cabins and sanitary spaces were also used to varying degrees.

Electrical All of the U.S. shipyards visited pre-cut cable to approximate size before installation, but there was very little cable pulling performed before launch. Some of the major electrical equipment was installed before launch, but not hooked up. The foreign shipyards bad all major electrical equipment installed and hooked up before launch, had cables pulled on block (to be completed/continued on adjacent blocks when erected) and smaller items, such as lights, fitted. Subsequent use was made of the ship's lights (powered by shore supply) in order to prevent a temporary service being installed.

Painting A number of problems were noted with painting in U.S. shipyards, of which three are most important. First, primers were not usually of a weld through type or were applied too thickly to allow welding to take place upon them. At present this is not a major problem due to the fact that initial stiffener locations marked by the burning machines are ground off and remarked by hand after plates have been joined to form panels. This is because the initial markings do no take account of weld shrinkage. Secondly, due to the length of time spent in storage or being worked upon after the treatment line, all yards perform a second blast and prime operation upon blocks. This prevents any outfit items which would be damaged by blasting being installed prior to this stage. After this stage they are installed. with the block in its final orientation. No foreign shipyard performed this second blast and prime operation. They merely touched up primer damaged during the production operations and cleaned the structure prior to applying the finished coatings. Only if a contract required it (e.g., for product tankers' cargo tanks) would a second surface preparation operation would take place. Finally, most finish painting in U.S. yards takes place after hull erection and launch and at present is associated with a large amount of staging.

Design/Drafting/Production Engineering/Lofting

This group is the one in which the greatest average difference between the U.S. shipyards and the foreign shipyards occurs. The minimum difference in technology levels is 0.5 and, even where the U.S. shipyards score highly (Steelwork Coding and Parts Listing) the competitors have a higher level. It is an example of where an industry has superior equipment but does not use it as effectively as competitors use less sophisticated equipment. The foreign shipyards have concentrated on getting methods correct before assessing whether they require the use of computers to support them. All elements discussed below have a difference in technology between U.S. yards and the foreign shipyards of at least 0.9.

Ship Design Although most U.S. shipyards surveyed have some design capability they are all severely limited in the commercial area. There is very little knowledge or information about modem merchant ship design, statutory requirements or classification society requirements in the whole of the U.S. shipbuilding industry.

Steelwork Drawing Presentation The major difference in the presentation of the drawings is that the foreign shipyards present the information to support the manner in which the work is to be performed and, as they produce steelwork in work stations, then the drawings are smaller and only include the information necessary to undertake the work at the relevant work station. The smaller drawings are easier to check so less engineering errors end up on the shop floor. Engineering errors were mentioned by the production departments of U.S. shipyards as a major problem.

Outfit Drawing Presentation The U.S. shipyards produce large, multi-trade drawings which cover a number of blocks or zones. This applies to both manufacturing and installation information. Usually both the manufacturing and installation information is contained on the same drawing. The foreign shipbuilder tend to produce separate drawings for the manufacture of work pieces and for their installation. Installation drawings are related to where the pieces are installed and could be work station related for installation in a steel shop, or zone/stage oriented for installation on-block or on-board. Installation drawings will also include all items to be installed in a workstation/zone /stage by all trades, or installers.

Production Engineering All U.S. shipyards apply production engineering techniques to their work and have good communication between the Engineering, Production Engineering, Planning, and Production departments. The major advantage which the foreign shipyards have is that they all have developed standards (both physical and procedural) which apply to merchant ships and which have been accepted by flag states and classification societies. These standards have been extensively production engineered and refined over a period of time.

Design for Production An effort is made in U.S. shipyards to include design for production in ships which have become contracts. This needs to be moved to the earliest stages of pre-bid design. There is a lack of knowledge of modem production techniques and of applying design for production among the naval architects who perform the initial designs in U.S. shipyards. The foreign shipyards have advanced the design for production of outfit items to a far greater extent than the U.S. shipyards.

Dimensional and Quality Control All of the surveyed U.S. shipyards have started the collection of dimensional information in their steelwork areas, but no shipyard has had the information analyzed in order to produce work instructions with acceptable tolerances for any stage in the process. The collection of data on the outfitting side has not been started yet. The foreign shipyards have all collected and analyzed information on their steelwork production processes and can be said to have them under control. Comprehensive procedures and standards have been developed and implemented. The result is greatly reduced rework and minimal excess stock on steel work. A great help in collecting information and keeping the processes under control is the establishment of work stations which produce identical, or very similar, items repeatedly. Foreign shipyards have gone onto apply the technique to outfit work and have largely succeeded in bringing this work under control. The foreign shipyards have instituted a system of self-checking at every stage and continually assessing whether the processes are still in control. The system is supported by the Quality Control and/or Accuracy Control Department in their yards. Continuous improvement programs are also in place.

MEDIUM DIFFERENCES

Steelwork Production

In no element of this group are the U.S. shipyards superior to their ‘competitor, although they are equal in one (Plate Stockyard). The major differences exist in the following elements.

Stiffener Cutting This is almost always performed by hand marking followed by hand burning.

Sub-assembly These are produced in random locations in workshops which also produce a variety of other work such as outfit steel items.

3D Unit Assembly A variety of practices apply including assembling where space is available, adding individual stiffeners to webs and pulling shell plate around, adding curved, stiffened panels to webs (the latter two methods at the same yard), erection outside, leaving excess stock on plates, and using welding procedures which result in significant distortion.

Outfit Steelwork Outfit steelwork is often produced in steel workshops in locations determined by where there is space available. No group technology is used.

Outfit Production and Stores

In the maintenance element of this group the U.S. shipyards are superior to the foreign yards. In most other elements they are very close, but for the following two elements there are significant differences.

Sheet Metal Work The sheet metal workshops in the U.S. shipyards are all extremely well quipped but none is organized on a group technology basis. They all appear to produce items which could probably be purchased cheaper from outside suppliers.

General Storage This was a somewhat surprisingly large difference, given that the warehouses in the U.S. shipyards are large, well run, departments. The difference is that each yard has huge warehouses in which a tremendous amount of material and equipment is held, whereas the competitors hold low levels of stock and some have developed really efficient just in time delivery of the required materials and equipment.

Organization & Operating Systems

All the shipyards surveyed scored highly in this group, but the foreign yards were consistently better, apart from purchasing in which the U.S. shipyards were marginally ahead. The two areas in which the

overseas competitors are significantly ahead are detailed.

Organization of Work This relates to the flexibility of the work force and the manner in which it is supervised. It was found that, although there are signs of trade flexibility and multi-skill training in the U.S. yards, work is still mainly done on a trade related basis. Supervision is also on a trade basis. All of the foreign competitors have a far more flexible, multi-skilled work force and agreements in place which will allow the full benefits of this to be achieved. The presence or absence of unions seemed to have little impact on these differences. The foreign shipyards also perform the work in workstations or zones and supervision is related to zones and not to trades.

Contract Scheduling This is actually quite well done in the U.S. shipyards but it is extremely well done by their foreign competitors. The major difference is that the foreign shipyards link strategic planning and tactical planning using computer systems which allow direct interaction between the two levels.

SMALL DIFFERENCES

Other Pre-Erection Activities

Although the average levels for the overall group. are fairly close, there are large differences in the individual elements. These occur in Outfit Parts Marshaling, which is one of only four elements in which U.S. shipbuilding is more advanced than their competitors, and Unit a Block Storage where the competition is more advanced than the U.S. shipyards. The group as a whole has a fairly high technology rating for both industries.

Outfit Parts Marshaling This is particularly good in the U.S. shipyards due to the fact that planning issues to stores and workshops timely lists of what items are required when and where, which allows these departments to produce “kits” or “pallets” of the required items.

Unit and Block Storage This is the element in this group in which the competitors are furthest ahead. It is a problem in most of the U.S. shipyards visited due to lack of area and also to the length of time which blocks spend in storage.

Layout and Environment

This group is rated as fairly low technology for both industries examined, and the differences within the group are all in the medium range. One element, Lighting & Heating, has a higher technology rating for the U.S. shipyards and this reduces the overall difference. With the exception of one U.S. shipyard and two of the foreign shipyards, all layouts and resulting material flows are constrained by the site and the ad hoc manner in which the yards have developed over the years.

COMPARISON WITH 1978 SURVEY

The technology survey of the U.S. shipyards which was conducted in 1978 did not apply weightings to the individual elements which were included in the study, so to compare like items the currently used weightings have been assigned to the results of the earlier study (Lowry, 1980). The results for the groups are shown in Table III below. Certain elements are now included in different groups than they were in the 1978 study, e.g., E2 E3 and E4 were previously Fl, F2 and F3.

The results in Table III show that in 16 years the average technology level in U.S. shipyards has increased by 0.9, from 2.5 to 3.4, while the foreign shipyards have increased by 1.1, from 2.9 to 4.0, i.e., the gap has widened slightly. The maximum attainable technology level in 1978 was 4.0 while the current highest level is 5.0, the increase in the level being judged to have occurred by 1990, over 12 years. Increases in average technology levels in the two studies could therefore be expected to be between 1.0 (5.0-4.0) and 1.25 (5.0/4.0). Both of the actual recorded increases are within the expected ranges, but significantly, that for the foreign yards is greater.

A brief examination of the changes in the groups shows the following. For Group A, Steelwork Production, the actual level of technology at present in the U.S. shipyards is now at the level it was in the foreign shipyards in 1978. However, the U.S. shipyards have actually progressed more than their foreign competitors, the average differences being 0.66 and 0.55 respectively. Both sets of yards have made the most progress in two areas, 3D Unit Assembly and Outfit Steelwork. The increases for 3D Unit Assembly are both 1.0, but the U.S. yards moved from 2.1 to 3.1 while the competitors changed from 2.9 to 3.9. In Outfit Steelwork the U.S. yards increased by 1.2, from 1.8 to 3.0, and the competitors rose by 1.6, from 2.5 to 4.1.

GROUP	1978 SURVEY U.S. SHIPYARDS	1978 SURVEY FOREIGN SHIPYARDS	1978 SURVEY DELTA	1994 SURVEY U.S. SHIPYARDS	1994 SURVEY FOREIGN SHIPYARDS	1994 SURVEY DELTA
A Steelwork Production	2.25	2.91	0.66	2.91	3.46	0.55
B Outfit Production and Stores	2.36	2.43	0.07	3.30	3.75	0.45
C Other Pre-Erection Activities	2.06	2.76	0.70	3.83	4.06	0.23
D Ship Construction	2.48	2.86	0.38	3.18	3.98	0.80
E Layout and Environment	2.33	2.89	0.56	2.94	3.31	0.37
G Design/Drafting/ Production Eng/Loft	2.92	3.17	0.25	3.45	4.33	0.88
H Organization and operating systems	2.98	3.03	0.05	4.04	4.67	0.63
OVERALL TECHNOLOGY LEVEL	2.5	2.9	0.4	3.4	4.0	0.6

Table III 1978 Survey Results Compared To 1994 Survey Results

Group B, Outfit Production and Stores had an average progress for both sets of yards of about what was expected, 0.94 for the U.S. yards and 1.32 for the competitors. U.S. shipyards have made the best progress in:

Electrical	1.2
General Storage	1.3
Pipework	1.3
Maintenance	1.4

while the foreign yards produced the highest gains in:

Woodworking	1.4
Electrical	1.6
General Storage	2.0
Auxiliary Storage	2.1
Sheet Metal Work	2.2

In pipe work the U.S. yards have made enough progress to be level with their competitors and in maintenance they have actually drawn ahead. In electrical and rigging they were about the same level in 1978 but have fallen behind by 0.5 now.

Group C, Other Pre-Erection Activities, is the group in which, on average. the most progress has been made, with the U.S. shipyards advancing by 1.77 against their competitors' 1.30. The gap has narrowed from 0.70 in 1978 to 0.23 at present. This is a significant group to make progress in as it demonstrates that more work **is** being performed in workshops rather than on the building berths. The major advances have been made in:

Block Assembly	1.6
Module Building	1.7
Outfit Parts Marshaling	3.1 to 5.0

In Group D, Ship Construction, the foreign shipyards have increased their technology level by an expected amount, 1.12 while the U.S. yards have improved by 0.70. The only improvements of an anticipated amount in the U.S. shipyards were in:

Welding	1.0
Pipework	1.1
Hull Engineering	1.2

During the period the foreign shipyards made significant improvements in

Pipework	1.5
Engine Room Machinery	1.6
Hull Engineering	1.7
Testing and Commissioning	1.9

Sheet Metal Work	2.0

In the painting area the U.S. shipyards have virtually stood still, only improving by 0.1.

Neither set of shipyards has shown a large improvement in Group E, Layout and Environment although the U.S. yards moved more than their competitors, 0.61 compared to 0.42. For both sets the element Layout and Material Flow has only increased by 0.1, indicating that the shipyard sites :are still constraints to an efficient layout and material flow.

Group G, Design/Drafting/ Production Engineering/Lofting is one in which the foreign shipyards have made twice as much progress as the U.S. shipyards, 1.16 compared to 0.53. This was from a fairly close position in the 1978 study, U.S. yards at 2.92, foreign yards at 3.17. The competitors have made the largest progress in:

Steelwork Dwg Presentation	1.3
Lofting Methods	1.3
Steelwork Coding Systems	1.5
Outfit Dwg Presentation	1.6
Parts Listing Procedures	1.9

Only in Lofting Methods have the U.S. shipyards made comparable progress, 1.2. In three areas, Steelwork Coding System, Parts Listing Procedures and Dimensional and Quality Control, the U.S. yards have lost leads they had. In Dimensional and Quality Control they are recorded at a lower level than in the 1978 survey, 3.0 compared to 3.2.

The two sets of shipyards studied in 1978 came out with identical technology levels in Group H, Organization and Operating Systems, 3.0. However, in the intervening 16 years the U.S. yards have improved by 1.06, while the foreign yards have increased their technology level by 1.64. The increase by foreign shipyards was gained by an almost uniform increase in every element of the group, while there were large variations in the changes of the U.S. shipyards. The largest increases produced by the U.S. yards were:

Contract Scheduling	1.3
Outfit Prod Scheduling	1.5
Outfit install Scheduling	1.6
Purchasing	1.9

In Purchasing the U.S. yards have actually overtaken their competitors by a small amount, 4.9 to 4.8.

PRODUCTIVITY

Using the information provided by the U.S. shipyards and three of the foreign shipyards, it was possible to estimate their productivities in terms of total employee man-hours required to produce a CGT. The world average productivity for similar sized shipyards (excluding U.S. shipyards) was developed.

Because the U.S. shipyards are currently building naval ships and relatively few of these are delivered annually, the output from each of the four U.S. shipyards was obtained over five years in order to establish a reliable average yearly value. The total output of the four shipyards visited over the past five years in terms of CGT and the man-hours required to produce it are shown in Table IV. The CGT produced was calculated using the estimated curve of CGT Coefficients shown in Figure 2.

TOTAL OUTPUT CGT	REQUIRED TOTAL W-HOURS
1,683,671	**314,274,641**

Table IV U.S. Shipyards Total Output and Required Man-hours 1989-1993

The average productivity over the period was 184.8 mh/CGT, with a range for individual shipyards of 237 mh/CGT to 119 mh/CGT. This probably presents a worse picture for the U.S. shipyards than actually exists, due to the fact that two of the yards considered undertook a significant amount of ship repair and conversion work. Also, some of the yards have “planning yard” and other white collar Navy support activities that produce spent man-hours without producing additional CGTs.

The three foreign shipyards for which productivity was measured were assessed over the previous three years. This was because merchant shipbuilders produce a greater number of ships per year and a reliable average annual output can be obtained over a shorter period than required for naval shipbuilders. The total output of the three shipyards in terms of COT and the man-hours required to produce them are shown in Table V.

The average productivity over the period was 40 mh/CGT, with a range for individual shipyards of 69 mh/CGT to 17 mh/CGT. Information on similar sized

YEAR	TOTAL OUTPUT CGT	REQUIRED TOTAL MAN-HOURS
1991	358,960	13,589,511
1992	380,720	15,781,367
1993	348,090	14,466,253
TOTALS	**1,087,770**	43,837,13l

Table V Three Foreign Shipyards Total Output and Required Man-hours 1991-1993

shipyards to the U.S. yards (but excluding the U.S. yards) indicates the average productivity is 88 mh/CGT with a range of from 180 mh/CGT to 17 mh/CGT.

COMPETITIVENESS

The competitiveness of the U.S. shipbuilding industry has been assessed in terms of the cost of producing a CGT compared with the same measure for its competitors. The competitors considered are again the three foreign shipyards which were visited and for which the productivity was calculated, plus the other world shipyards considered to be competitors and for which data was available.

In order to calculate the cost of producing a CGT, the effort in terms of employee man-years required to produce a CGT is multiplied by the total annual cost of employing a shipbuilding worker. This is produced for each individual shipyard and the average obtained by dividing the sum by the number of yards. The results are shown in Table VI.

KEY EVENT TIME SCALES

The average key event time scales for European competitors building merchant ships are shown in Figure 3 for various ship types and sizes. Ships considered are all first in a series (or one ship contracts). The best Japanese shipyards will have total time scales of about 80% of the European figures. Since the U.S. shipyards were not building merchant ships, the actual competitive position cannot be ascertained, but the information will indicate time scales which must be attained in order to become competitive. There is a clear correlation between time scales and cost, and thus competitiveness is determined **by** a combination of these interrelated variables.

RECOMMENDED AREAS TO TARGET IN ORDER TO INCREASE COMPETITIVENESS

There are a number of areas of improvement that should be targeted by the U.S. shipbuilding industry. These are presented below, in two categories, for most important and secondary areas.

Critical Areas for Improvement

Business Plan

The U.S. shipyards must focus on the product range which they intend to build and determine their capacity, targeted output and build cycles. They also need to develop targets for costs and a pricing policy.

	U.S. YARD AVERAGE	VISITED FOREIGN AVERAGE	ALL FOREIGN AVERAGE	ALL FOREIGN RANGE
MAN-HOURS WORKED PER YEAR	**1,829**	**1,805**	**1,963**	**1$50-2,600**
MAN-HOURS/CGT	**184.8**	**40.0**	**88.0**	**17.0 -180.0**
COST/EMPLOYEE YEAR	**$52,500**	**$63,455**	**$48,690**	**$11,290 - $104,960**
COST/CGT	**$5,314**	**$1,121**	**$1,296**	**S697 - $1,653**

Table VI Competitiveness Comparison

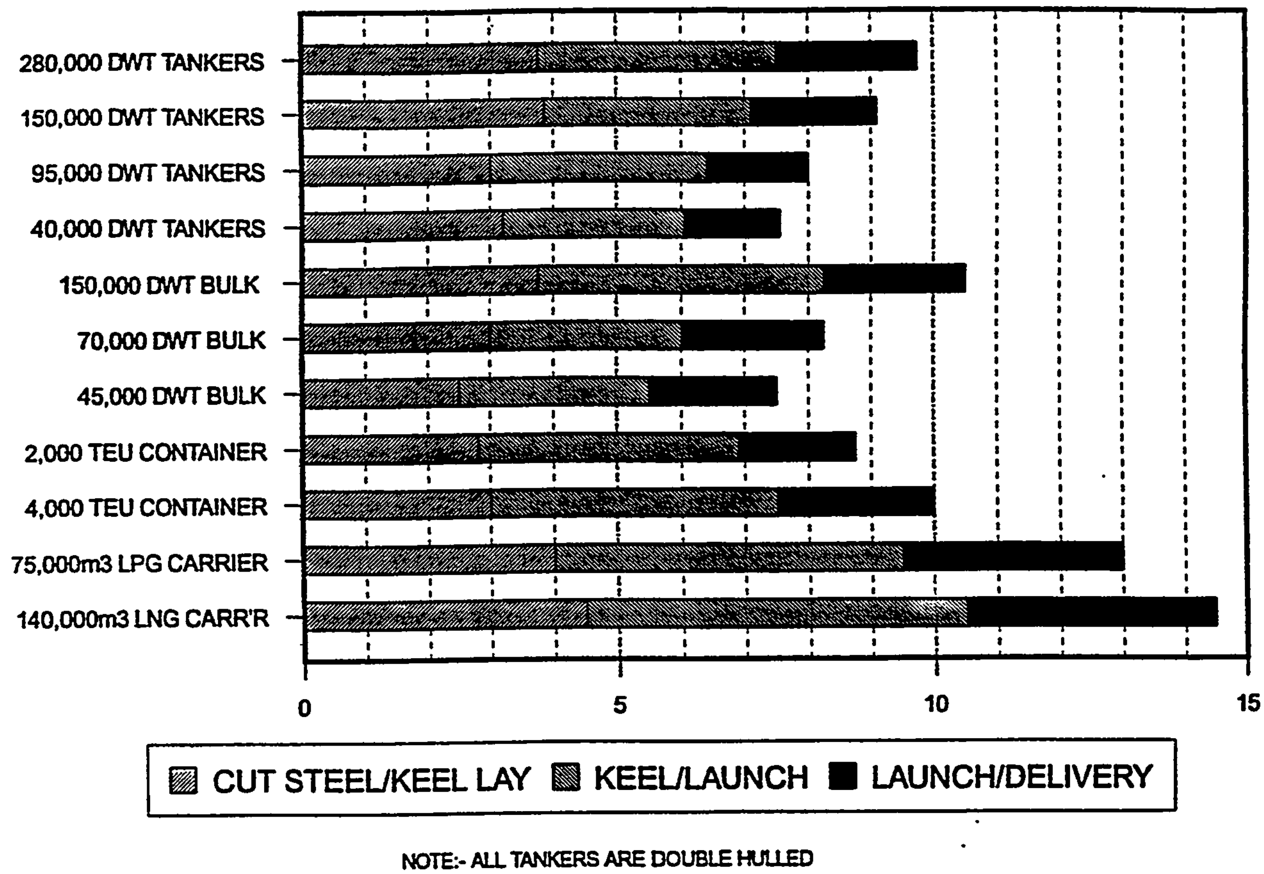


Figure 3 Current Best European Build Cycle Times, Months

Shipbuilding Policy

Once the target product mix has been determined then the optimum organization and methods must be developed in order to produce them in the most cost effective manner. A shipbuilding policy should address facilities development, productivity targets, ship definition strategy, production organization and methods, planning and contract procedures, and make, buy or subcontract policies. Successful foreign competitors have first rationalized the shipbuilding system before addressing significant facilities developments.

Marketing

Marketing must target the owners of the ship types and sizes which are identified in the business plan in a proactive manner. These owners should then be visited to inform them what the shipyard can offer to satisfy their requirements.

Design and Engineering

It is strongly recommended that all shipyards have their own design and engineering departments sufficient to fulfill their needs.

If designs do not include "design for ease of production" and take account of a yard's facilities and production methods, shipbuilding will be a great deal more costly and time consuming.

Engineering information needs to be produced on time and in the sequence specified by the planning department and should contain information which reflects the manner and place in which the work is to be performed. It should also be produced in accordance with a ship definition strategy.

It is unlikely that an outside organization could satisfy all of the above requirements. If they are not met then the shipbuilding process is not under control.

There is a lack of experience in modern merchant ship operations, design, regulations and the associated up to date building methods among naval architects and engineering staff in the U.S. shipbuilding industry. This expertise is essential and needs to be acquired quickly if the industry hopes to successfully penetrate the commercial markets.

Total Quality Management and Accuracy Control

U.S. shipyards have been slow to implement total quality management (TQM) principles and to adopt accuracy control procedures. TQM has proven to be a requirement in any manufacturing system that requires input from all levels of the organization in order to continuously improve productivity. World class shipyards employ TQM in some form, including training from top to bottom in the organization.

The need for accuracy, based on statistical techniques is described in the discussions of steel, outfit and painting processes. Accuracy control is directly related to improvements in cycle time, a key factor in international competitiveness.

Material Management

U.S. shipyards do not employ just in time approaches to material management. This includes identification, purchasing, warehousing, marshaling, handling and assembling. Overseas shipyards control costs by the application of this manufacturing philosophy. Significant waste, rework, and monitoring is the result of the lack of just in time material management.

Purchasing

The yards need to build up a database of suppliers of equipment for merchant ships, together with the means of recording their performance for future use. These suppliers should be worldwide. Continuing efforts to improve supplier relationships are critical for achieving worldwide competitiveness.

Purchasing should aim for just in time delivery of materials and equipment to the shipyard in order to reduce capital tied up in stored goods and the storage area necessary. Moving to the universal application of this practice, even for U.S. Navy or other government work, will provide long term benefits to both the shipyards and the government. Suppliers are becoming used to just in time deliveries that are being required by all industries, which should help U.S. shipyards in these efforts.

Second Blast and Prime Operation

This should be completely eliminated from the shipbuilding process. It does not occur in any modern merchant shipbuilding yard and should be unnecessary. The elimination of this operation will allow additional outfit materials and equipment to be installed on unit, or on block, earlier than at present. This is because at present items which would be damaged by blasting have to be omitted until after the operation takes place.

Outfitting

Only one of the U.S. shipyards visited had collected data on an outfit manufacturing or installation procedure in order to have them analyzed as part of a self-checking statistical process control system. This should be addressed, as all aspects of ship production must be brought under control in the statistical meaning of the word.

Outfitting should be performed earlier in the building process so that, for example, deckheads are outfitted while they are in an inverted position in a workshop. Too much deck level outfitting occurs on block while the block is in its final orientation. Equipment should be installed "blue sky" and not moved in horizontally when the block ring has been completed. More electric cabling could be installed on unit and on block, with excess lengths which have to be run to adjacent, or further, blocks left coiled in place.

The yards should develop standard equipment units for merchant ships and incorporate them into the designs for these ships. The framework for such units should support the units without the need for temporary stiffening, which occurs at present.

Outfit workshops should be organized on a group technology basis with groups of similar work being produced in dedicated workstations using standard procedures and tools.

The use of welded studs and bolts for the attachment of pipe hangers, cable ways, vent trunks, electric lights and other outfit items should be greatly extended.

When a ship is in the water the required services should be led in planned routes, kept clear of the deck, and arranged in modular form to allow for removal or expansion without interruption to the remainder of the services. The early hookup of the ship's electric lights will allow them to be used via shore supply in order to reduce the services required.

Painting

This is an area where Japanese shipyards are making large investments in order to improve productivity and quality. Painting should be so organized that finish painted blocks go to the ship assembly berth. The blocks should be painted in paint cells or similar. During the build process any damaged primer should be wire brushed and touched up to maintain protection.

Mixing Naval and Merchant Ship Construction

There is some circumstantial evidence to suggest that it is counter productive to build commercial/merchant ships (of whatever type) and military ships in the same shipyard using the same engineering and production personnel. While some internationally competitive shipyards successfully mix merchant and naval shipbuilding, most world class shipyards concentrate totally on merchant ship construction.

In principle, some types of small to medium size merchant ships have some characteristics that are similar to those of naval combatant ships of comparable size. The important characteristics are (1) where the functional role of the vessel requires extra, specialist **crew** members to operate the vessel while it is underway, **(2)** it has special, often technically sophisticated, on-board engineering systems over and above those required to navigate and provide the propulsion and crew accommodation services, and (3) there is a high "packing density" of engineering systems in compact machinery spaces.

Commercial vessels that have these characteristics include:

- oceanographic survey vessels;
- deep sea fishing vessels;
- chemical, LNG, LPG carriers; and
- passenger liners and ferries.

The arrangement of these vessels and comparable naval vessels should reflect a consistent approach by a shipyard to the use of an assembly strategy that is a consistent application of PWBS and GT principles.

There are a few features associated with the construction of naval vessels that cause some operational difficulties. These are the extensive operational and other documentation and the large number of engineering change orders that arise from requests from the Navy and from problems with government furnished equipment.

One possibility is to build merchant and naval vessels on adjacent, but operationally independent sites. A second possibility is for the government to significantly revise it's behavior as a customer to shipyards building both Navy and merchant ships.

Whatever strategic approach is adopted, great care is required to ensure that a shipyard's ability to compete effectively with those shipyards that concentrate on specific markets for merchant ships is not undermined.

ADDITIONAL AREAS FOR IMPROVEMENT

A second level of areas for improvement were also identified. These are considered to be important, but not as critical as the items described above. This second level list includes:

- build strategy use;
- steel stockyard, reduction in stock levels;
- treatment line, use of weld through primers;
- plate burning and marking, use of shrinkage allowances;

- forming, use of line heating and nc machines (especially for stiffeners);
- sub-assembly, work performed in defined Workstation,
- flat panel assembly, updating of panel lines, use of more automation and elimination of welded fairing aids;
- curved unit assembly, use of one sided welding and improved distortion control;
- block assembly, produce larger, more fully outfitted blocks and employ ground level transport systems;
- staging and access, dramatically reduce staging requirements;
- organization of work improve trade flexibility and provide area rather than trade supervision and
- production control, reduce and level work package size and develop real time feedback and control systems.

CONCLUSION

This paper is intended to provide information to U.S. shipyards as they **seek** to become commercially competitive. To some degree, the fact that U.S. yards have lost ground compared to their foreign competitors since 1980 **is** cause for concern. Without commenting on the reasons for this situation, the need to improve should be very clear.

There are some reasons for optimism contained in the results. Labor costs and average hours worked for U.S. yards are world competitive. Additionally, technology improvements needed are generally of the soft or management technology type, rather than facility or hardware type. Thus, major capital improvements are not required to produce major productivity improvements.

It is hoped that the recommendations will provide a framework for U.S. shipyards to conduct internal evaluations to set a course for international commercial competitiveness. These plans must be prepared and implemented in order to enable the industry to survive in the coming decade.

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